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PROTOTYPE OF A SPACE HOUSE

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16. Abstract The Bios-3 experiment on life support in a closed-cycle environment is described (first reported at the 24th International Astronautical Congress, Baku, October 1973; see LOC/FRD Item No. 1425). Three subjects lived in a closed-cycle environment for six months. This environment allowed 95% recycling of water and supplied 1/5 of their food. It consisted of four chambers: living quarters, chorella cultivation chamber, and two phytotrons (one for growing wheat, the other for growing vegetables: turnips, carrots, dill, cabbage, etc.). These were grown hydroponically, using xenon lamps for light. For each of the three subjects there was about 200 g of wheat and 388 g of vegetables per 24 hours. The main water source was condensation from the phytotrons and chorella cultivators. Human wastes were mineralized and partially utilized by the chorells, while waste water (from dishwashing, etc.) was utilized by the wheat and vegetables.			
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PROTOTYPE OF A SPACE HOUSE

Sergey Vlasov

As everything which exists on earth lives on the same amount /23^{*} of gases, liquids, and solids, which never diminish or increase, so we too will be able to live forever on an interplanetary station with the reserve of matter which we take with us.

K. Tsiolkovskiy

In a fantastic sketch by A. Belyayev, "Eternal Bread," Professor Broyer creates a culture of microorganisms consisting of all the elements necessary for human nourishment. "The eternal bread" obtained was nourishing and tasty. Swallowing molecules of air, it grew inexorably. One kilogram of it was enough for a man for his entire life. And in any case, it would have proven sufficient to feed a ~~cosmonaut~~ astronaut in prolonged flight. But so far this is only a fantasy - people are obliged to bring the products of the earth into space with them.

If one takes the daily norm consumed by a man--food, 700 g., drinking water, 2500 g., oxygen - 800 g., sanitary and living water - 5000 g., then for a flight lasting one year with a crew of three people about 10 tons of supplies are needed. For flight to Mars and back, a crew requires as much as 30 tons of supplies. As a figure for comparison: the weight of a three-passenger space-ship like "Soyuz" is 6.5 tons.

Meanwhile, the transport of food products is very expensive. Taking transportation expenses into account, a loaf of bread weighing 1 kg. would cost more on Mars than 1 kg. of gold.

* Numbers in the margin indicate pagination in the foreign text.

In the course of twenty-four hours the human organism releases into the surrounding environment more than 2.5 kg. of waste products. In a three-year period, calculating for a crew of three people, this will come to more than 8 tons. How can the unnecessary substances be disposed of? By throwing them out of the spaceship? No, simply throwing out the waste products is inadmissible. Space must not be polluted.

For flights to other planets, the systems of life support (SZhO) which exist today are unsuitable. A closed cycle with rotation is necessary, in which the substances produced by the organism, after a number of transformations, might again be suitable for the space crew. One of the studies leading to the creation of such a system was the 6-month Krasnoyarsk experiment, which was conducted by a group of scientists from the L. Kirenskiy Institute of Physics of the Siberian Division of the USSR Academy of Sciences. In this experiment the life support system was constructed on basically the same principles which have been undergoing natural testing on this planet for several billion years. /29

"Bios-3" - the experimental complex of the Krasnoyarsk scientists - consisted of four sections. One was the living quarters. Another was occupied by two cultivators with unicellular green chlorella. In a 24-hour period it produces 100 times its volume in oxygen. Its mass increases several times. Besides, the chlorella, although it is not the only item, is completely suitable for nourishing a man: it consists of 50% protein, 20% fat, 10% carbohydrates, about 10% mineral salts, and also vitamins A, C, and the B group.

In the "Bios-3" complex, the chlorella was not used for food, but only for regeneration of oxygen and water. The pro-

ductivity of the two cultivators is 2000 liters of oxygen per 24 hours (one man needs approximately one-fourth as much).

Two more sections are phytotrons, 20 kilovolts each. In one was short-stemmed wheat, in the other - vegetables: beets, carrots, dill, cabbage, turnips, onions, cucumbers, radishes, and sorrel. The plants were grown according to the method of hydroponics, that is, without soil, in water solutions of mineral salts. And the consumption of salts was much less than the weight of the synthesized nutritive biomass.

In each phytotron there were 20 xenon lamps, substituting for the light of the sun. Of all the plants, the most productive were wheat and carrots--their harvest even exceeded record levels for field conditions. The wheat grew by a method of a conveyor of 14 stages, the vegetables, by a conveyor of 6 stages. Thus, on the average for each of the three experiments in a 24-hour period there were 200 g. of grain and 388 g. of fresh vegetables. Part of the grain was selected for seeds for sowing and for analysis, and they baked bread from the rest.

The experimental greenhouse only partially satisfied the requirements of the crew for food: 4/5 of the rations consisted of products previously dehydrated under vacuum conditions. They preserve the qualities of the natural foods and are more than 5 times as light. Perhaps the efficiency of the system was only 20%. But figures of 100% will never be successfully achieved, for losses are unavoidable. As the calculations show, the maximum amount is 95%.

The source of water in the system was condensates from the phytotrons and chlorella cultivators. After reprocessing in ion-exchange resins and coal, this water was fit for drinking.

The solid and liquid human wastes after mineralization (decomposition into oxides, mineral salts, and water) were partially absorbed by the chlorella. And the entire sewage and living water (for bathing, washing of linen, washing dishes) entered into the nourishment solutions for the wheat and vegetables.

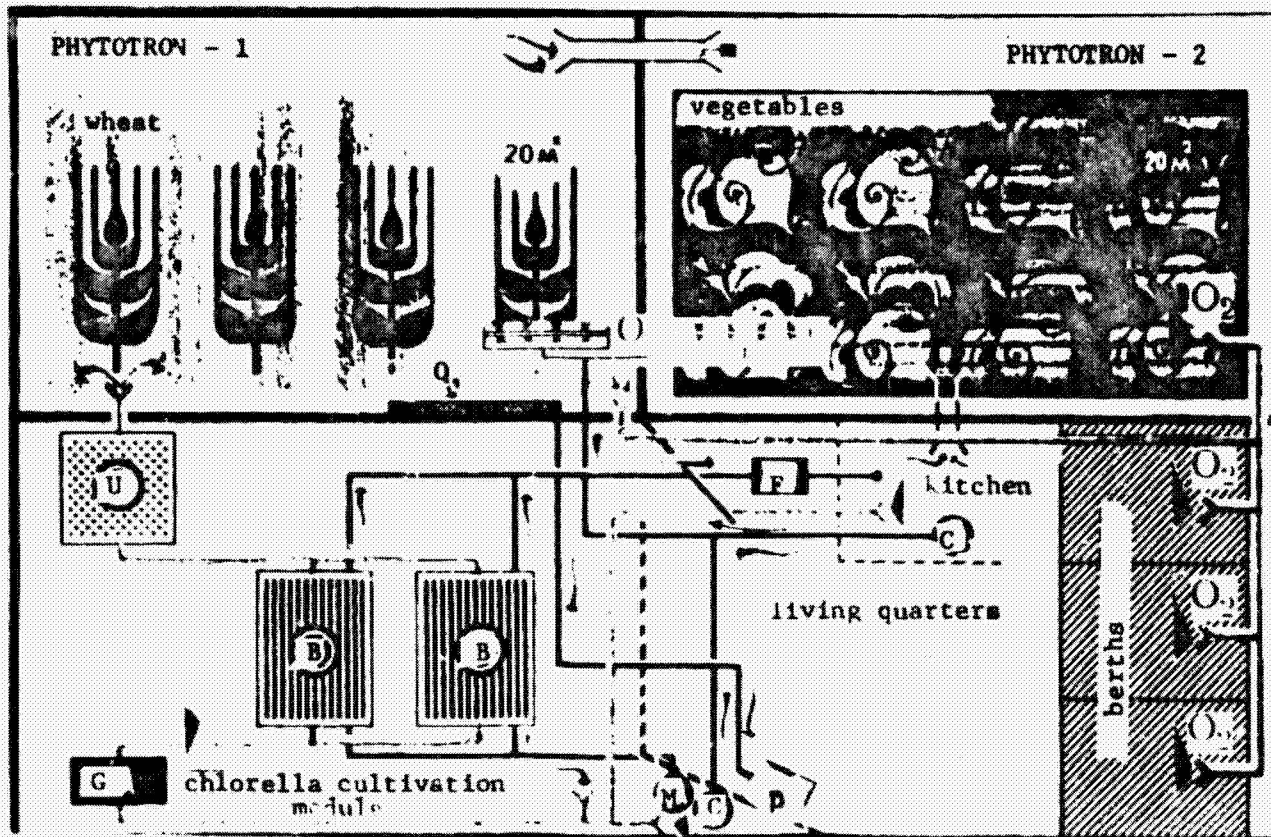
Thus in the "Bios-3" complex a partially closed life-support system was achieved. By means of light energy it completely regenerated the atmosphere, returned to rotation up to 95% of the water, produced 1/5 of the food products, including fresh vitamins, 26% of the carbohydrates, 14% of the proteins, and about 3% of the fats.

In the "Bios-3" experimental complex people were not only a "link in the mass exchange," but also operators. They collected information, adopted decisions, and supervised all technological processes. This, of course, does not mean that for the entire 6 months the experimenters were thrown onto the mercy of fate. Outside the complex, two people were on duty in shifts --an operator and a physician.

The experiment in Krasnoyarsk has been completed. But much still must be studied and understood.

How can the efficiency of the system be improved? Which plants are preferred? What can be done so that, like some tropical plants, they will bear fruit without a "rest?"

Nonetheless, it is completely clear that the mastery of distant space will begin only after the creation of an irreproachably working closed life-support system. And although it is an unusually difficult matter, such a system will nevertheless be created.



Scheme of gas- and water-exchange in the "Bios-3" experimental complex. The paths of movement of the gases are shown in orange lines, those of water, in black lines. The direction of movement is indicated by the blue arrows. The letters designate the following: B- chlorocella cultivators, G - gas blower, U - coal filter, C - kitchen and toilet waste-water collectors, Q - water vapor condensor collector in the phytotron, D - unit for boiling and storing non-drinking water, M - urine collector, F - sorption unit for completion of drinking water purification.